Fig.1

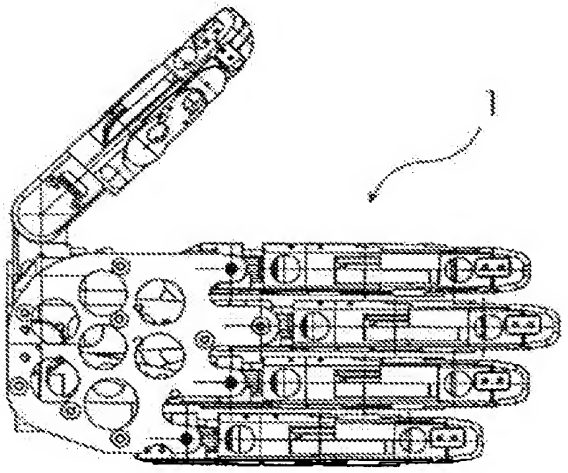


Fig.2

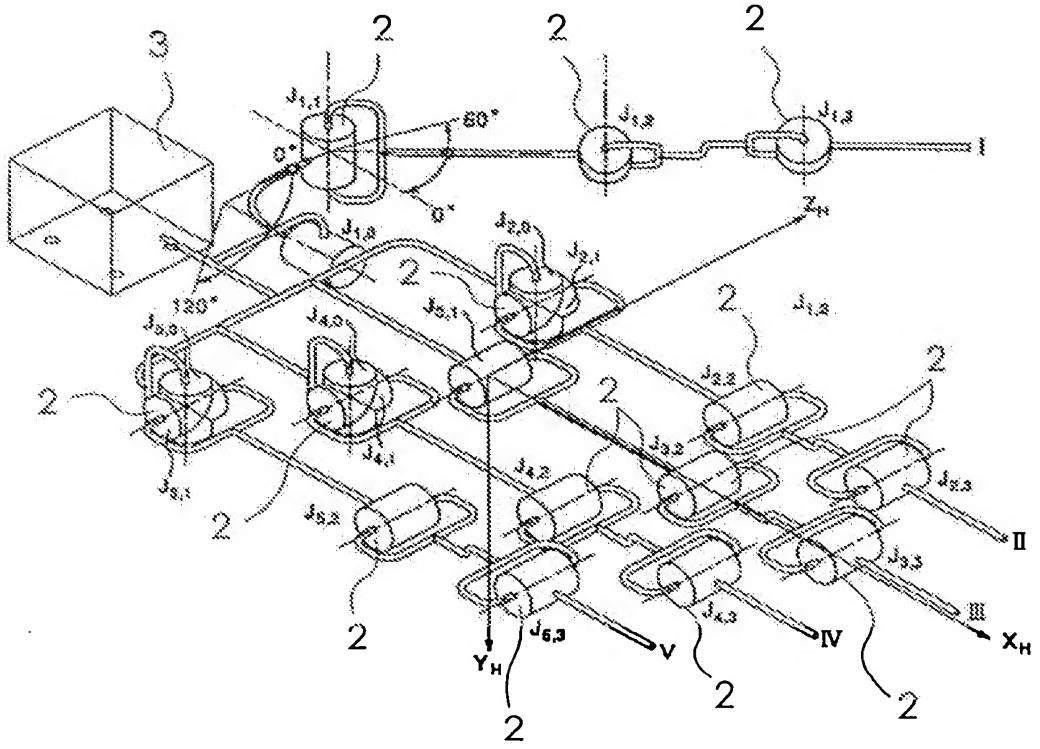


Fig.3

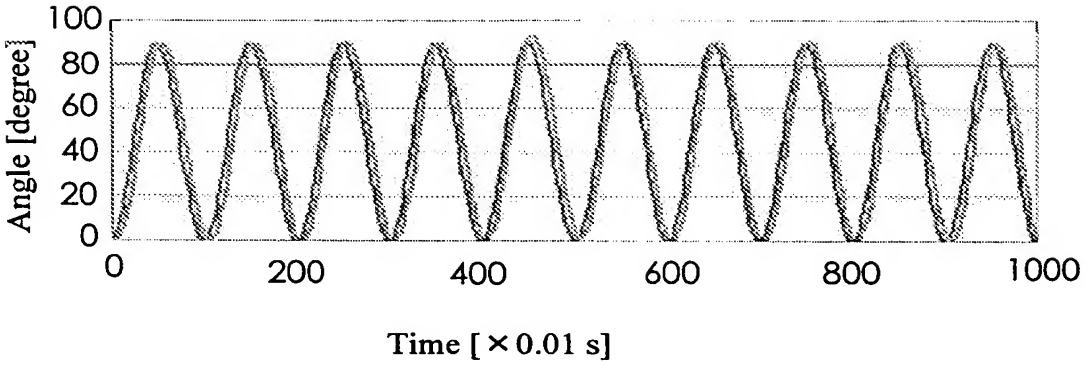

Angle [degree]
100
80
60
40
20
0
0
200
400
600
800
1000
Time [×0.01 s]

Fig.4

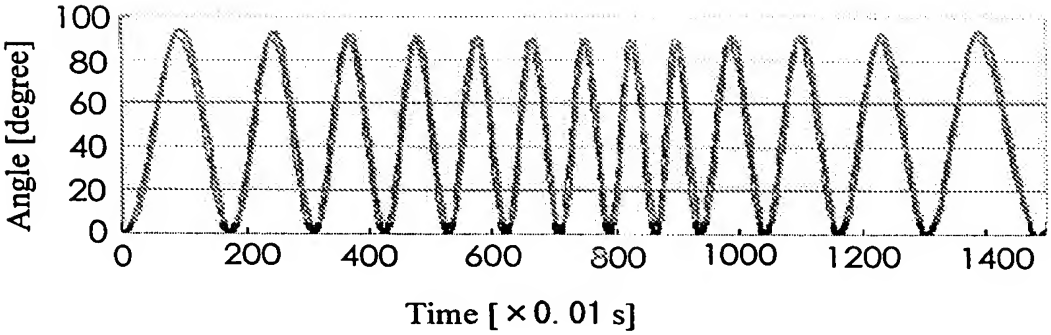
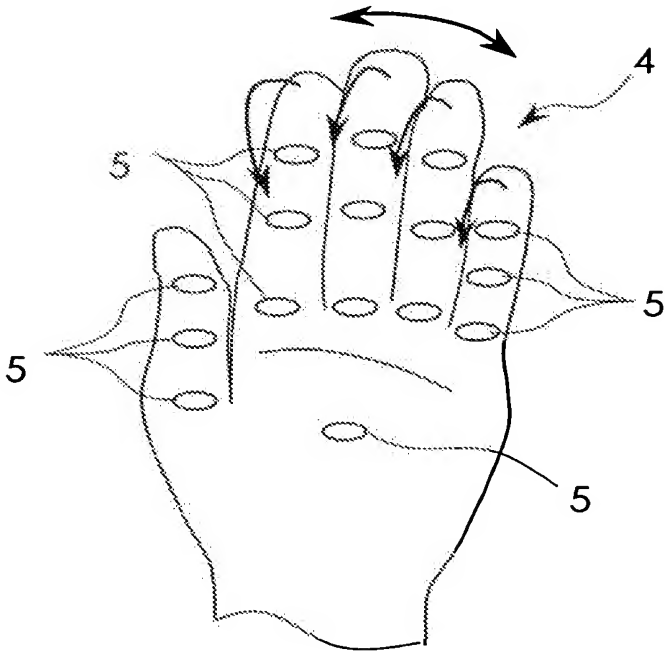

Angle [degree]
100
80
60
40
20
0
0
200
400
600
800
1000
1200
1400
Time [×0. 01 s]

Fig.5



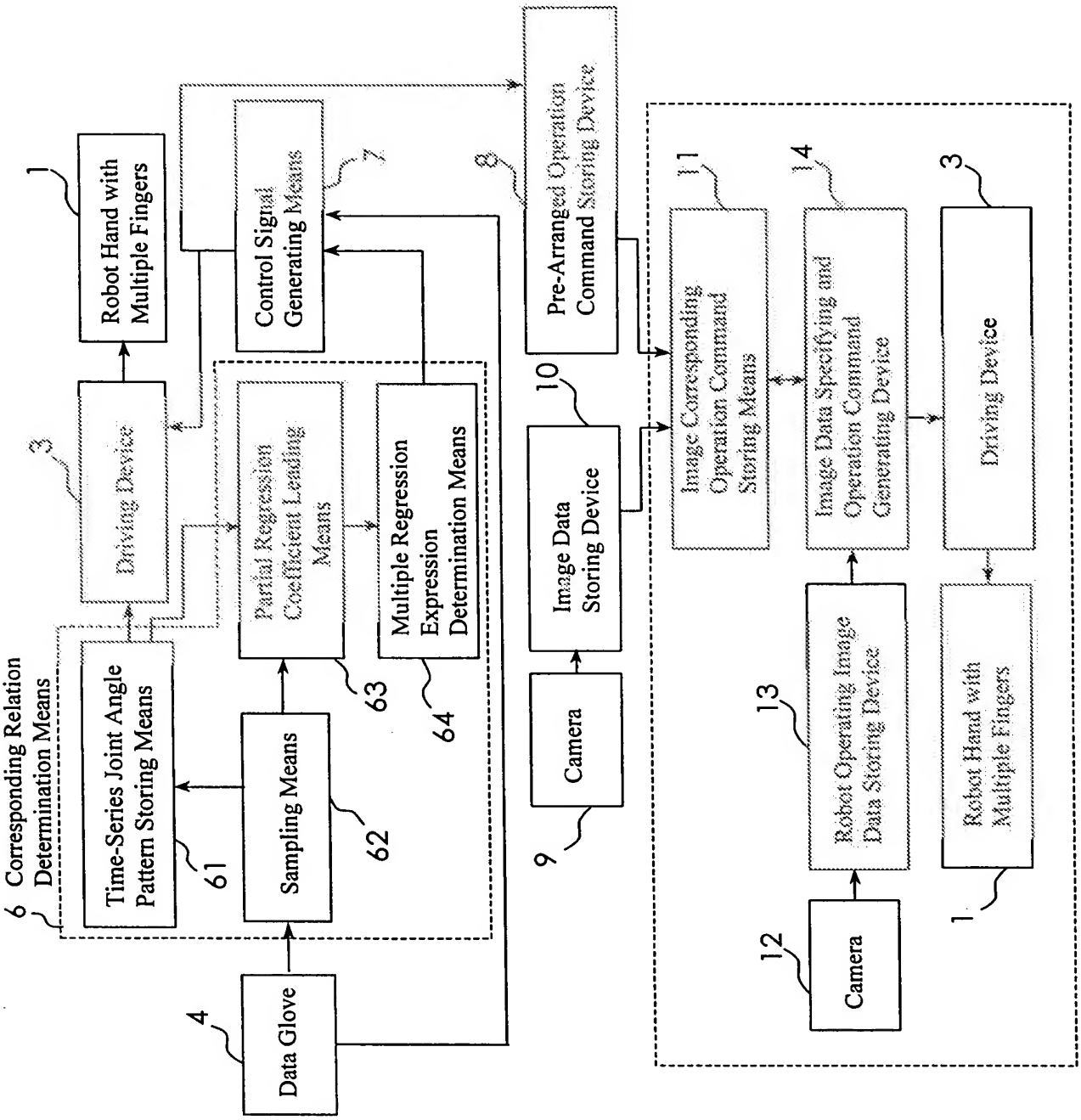

Robot Hand with Multiple Fingers
1
Driving Device
3
Data Glove
4
6 Corresponding Relation Determination Means
Time-Series Joint Angle Pattern Storing Means
61
Sampling Means
62
Partial Regression Coefficient Leading Means
63
Multiple Regression Expression Determination Means
64
Control Signal Generating Means
7
Pre-Arranged Operation Command Storing Device
8
Camera
9
Image Data Storing Device
10
Image Corresponding Operation Command Storing Means
11
Camera
12
Robot Operating Image Data Storing Device
13
Image Data Specifying and Operation Command Generating Device
14
Driving Device
3
Robot Hand with Multiple Fingers
1

Fig.6

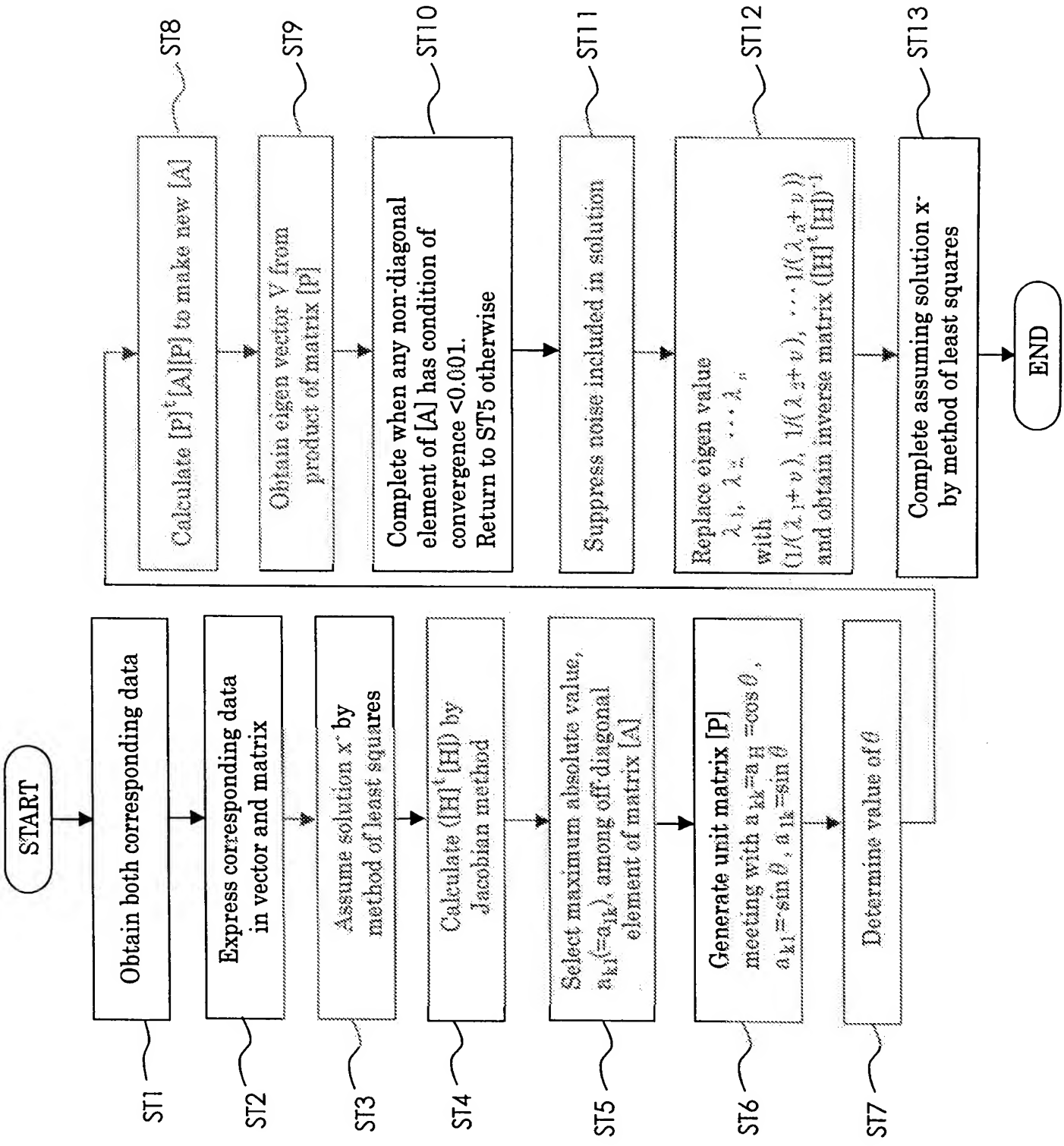

START
Obtain both corresponding data
ST1
Express corresponding data in vector and matrix
ST2
Assume solution x' by method of least squares
ST3
Calculate ([H]^t [H]) by Jacobian method
ST4
Select maximum absolute value, a_kl(=a_1k), among off-diagonal element of matrix [A]
ST5
Generate unit matrix [P] meeting with a_kk=a_ll=cos θ, a_kl=-sin θ, a_lk=sin θ
ST6
Determine value of θ
ST7
Calculate [P]^t [A][P] to make new [A]
ST8
Obtain eigen vector V from product of matrix [P]
ST9
Complete when any non-diagonal element of [A] has condition of convergence <0.001. Return to ST5 otherwise
ST10
Suppress noise included in solution
ST11
Replace eigen value λ1, λ2 ... λn with (1/(λ1+υ), 1/(λ2+υ), ... 1/(λn+υ)) and obtain inverse matrix ([H]^t [H])^-1
ST12
Complete assuming solution x' by method of least squares
ST13
END

Fig. 7

Fig.8

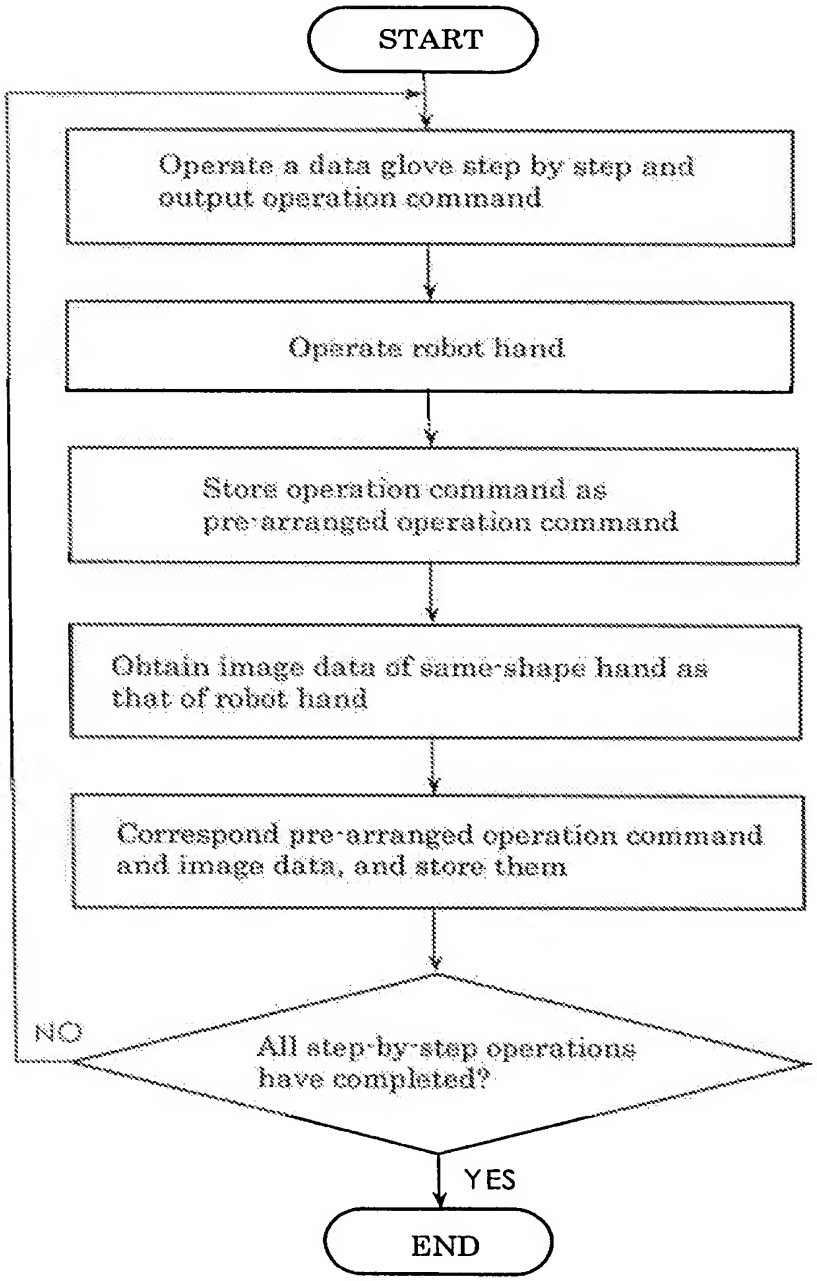

START
Operate a data glove step by step and output operation command
Operate robot hand
Store operation command as pre-arranged operation command
Obtain image data of same-shape hand as that of robot hand
Correspond pre-arranged operation command and image data, and store them
All step-by-step operations have completed?
NO
YES
END

Fig.9

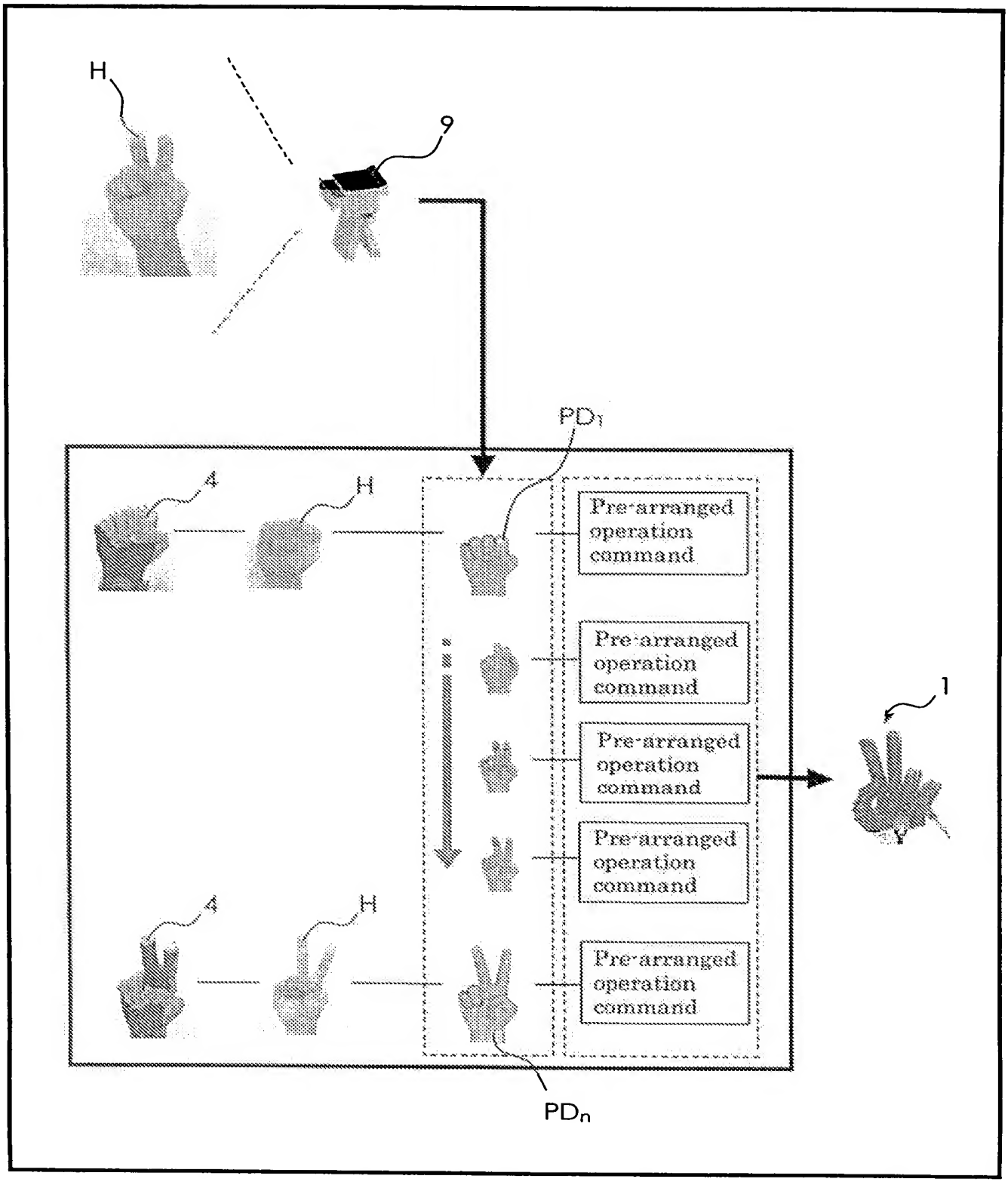

H
9
PD1
4
H
Pre-arranged operation command
Pre-arranged operation command
Pre-arranged operation command
Pre-arranged operation command
Pre-arranged operation command
1
4
H
PDn

Fig.10

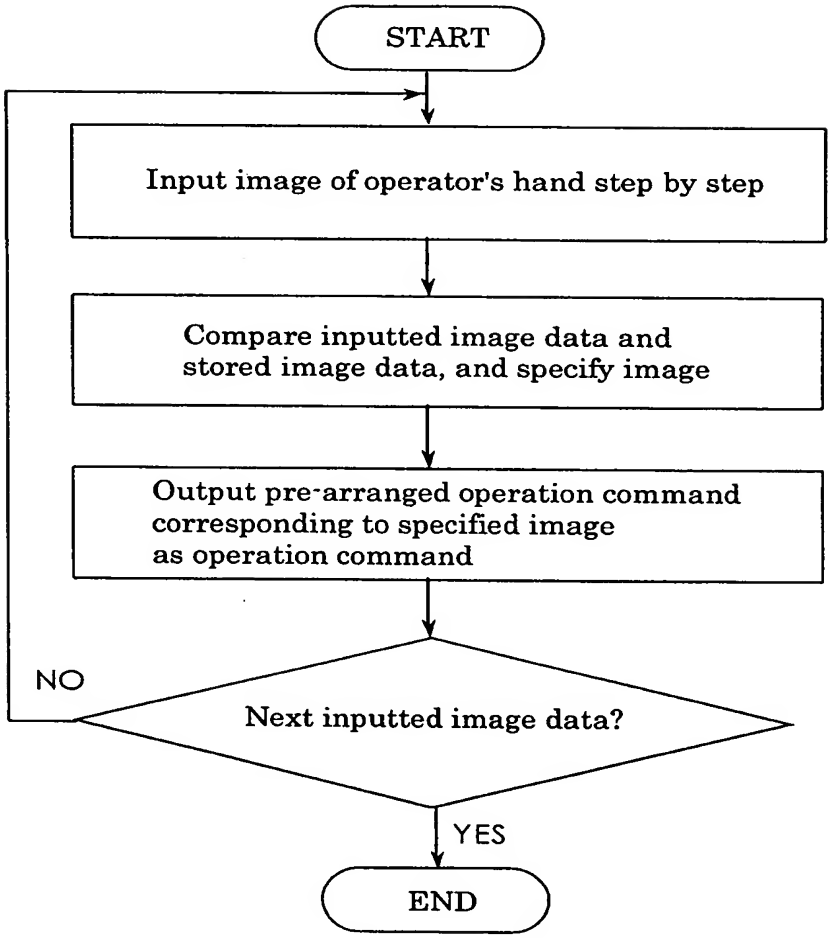

START
Input image of operator's hand step by step
Compare inputted image data and stored image data, and specify image
Output pre-arranged operation command corresponding to specified image as operation command
NO
Next inputted image data?
YES
END

Fig.11

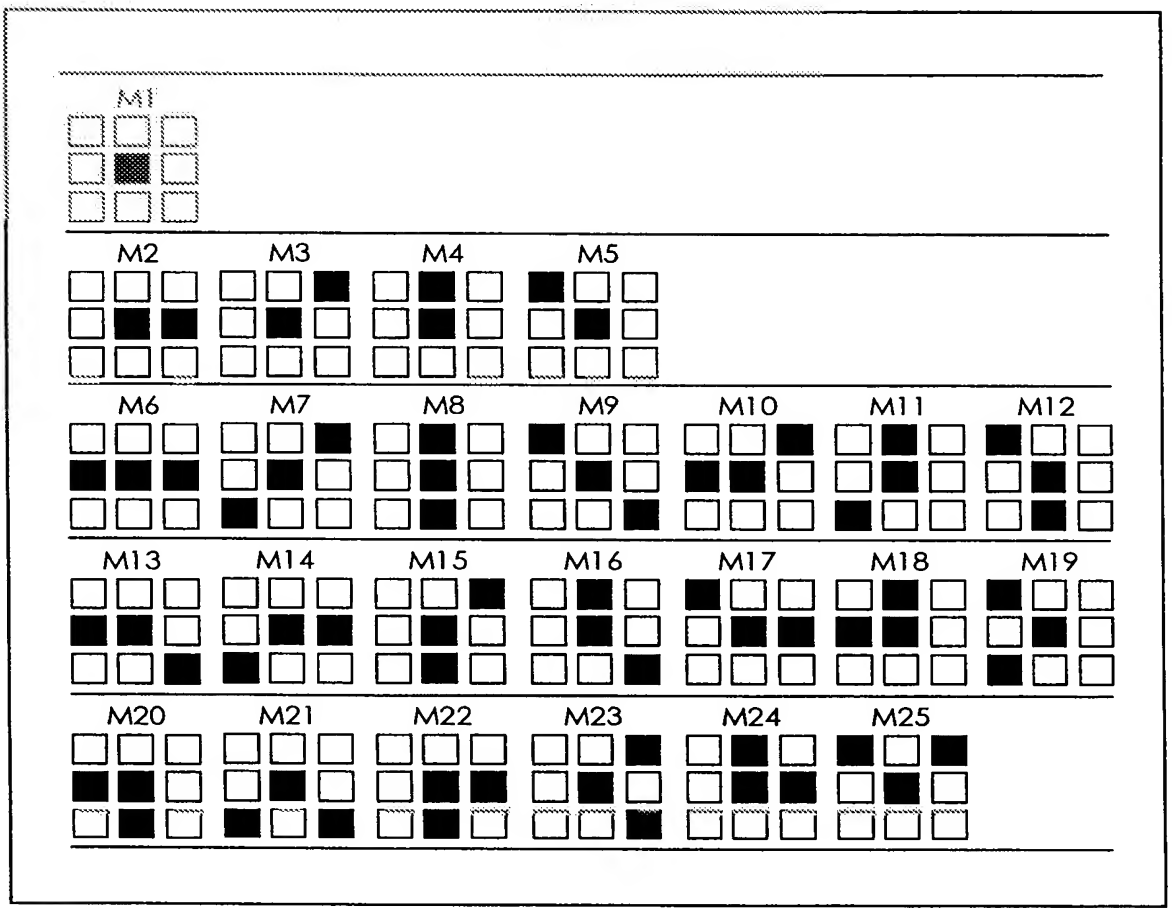

M1
M2
M3
M4
M5
M6
M7
M8
M9
M10
M11
M12
M13
M14
M15
M16
M17
M18
M19
M20
M21
M22
M23
M24
M25

Fig.12

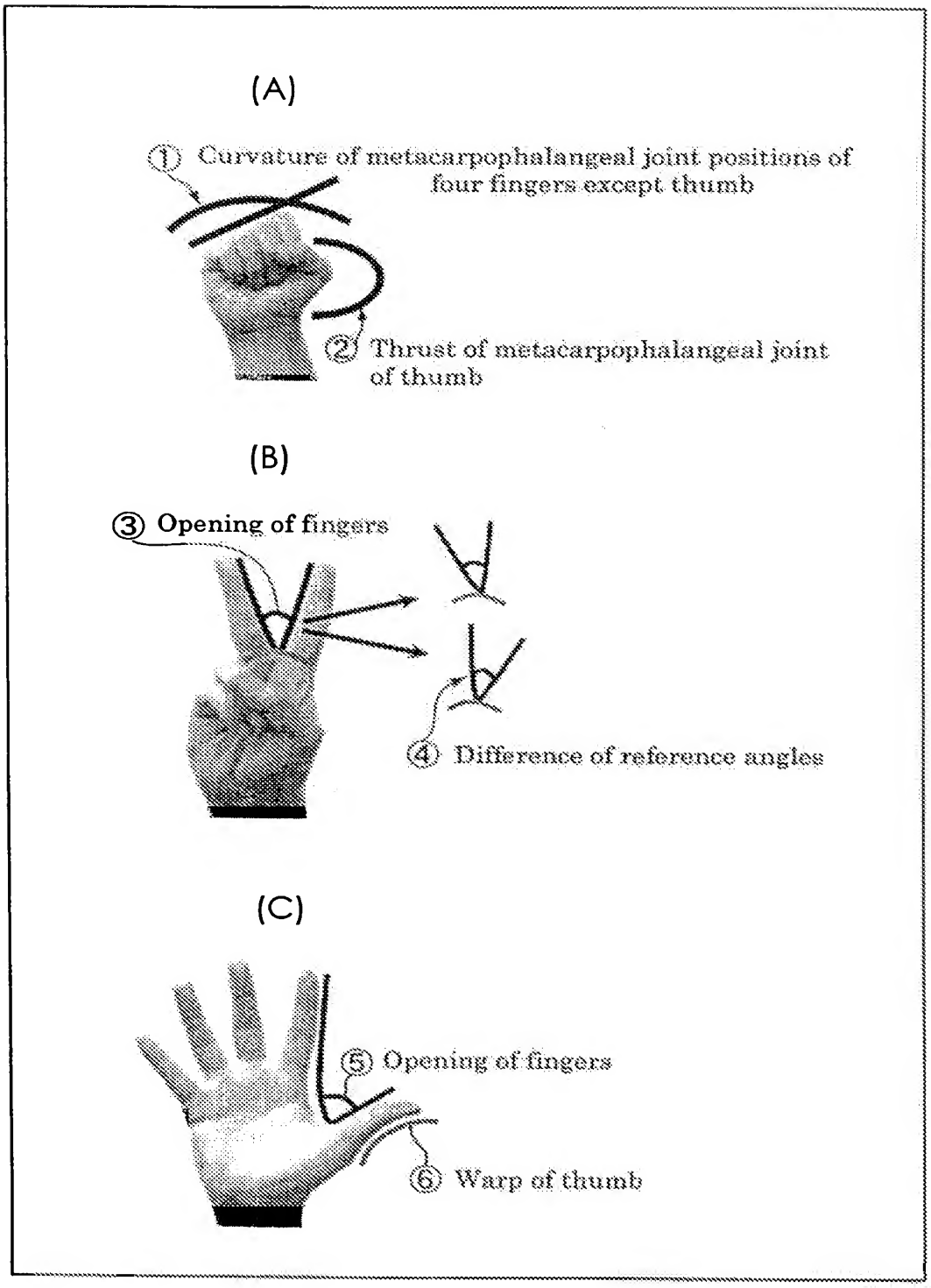

(A)
① Curvature of metacarpophalangeal joint positions of four fingers except thumb
② Thrust of metacarpophalangeal joint of thumb
(B)
③ Opening of fingers
④ Difference of reference angles
(C)
⑤ Opening of fingers
⑥ Warp of thumb

Fig.13

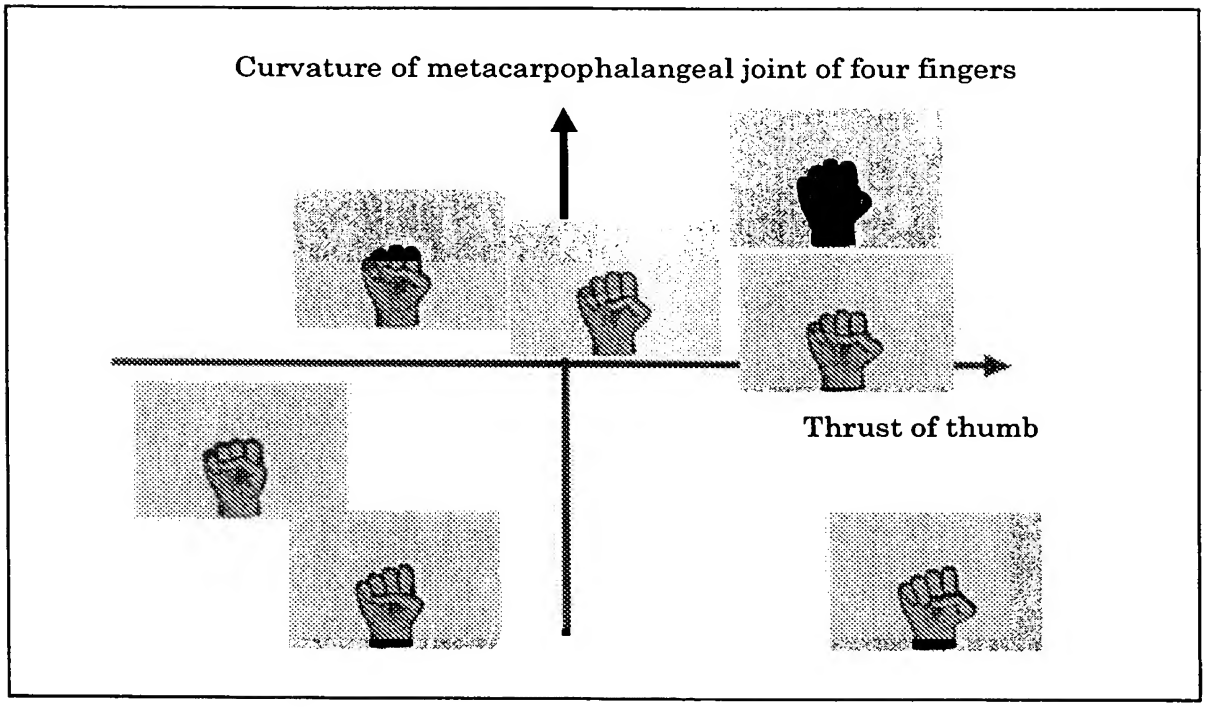

Curvature of metacarpophalangeal joint of four fingers
Thrust of thumb

Fig.14

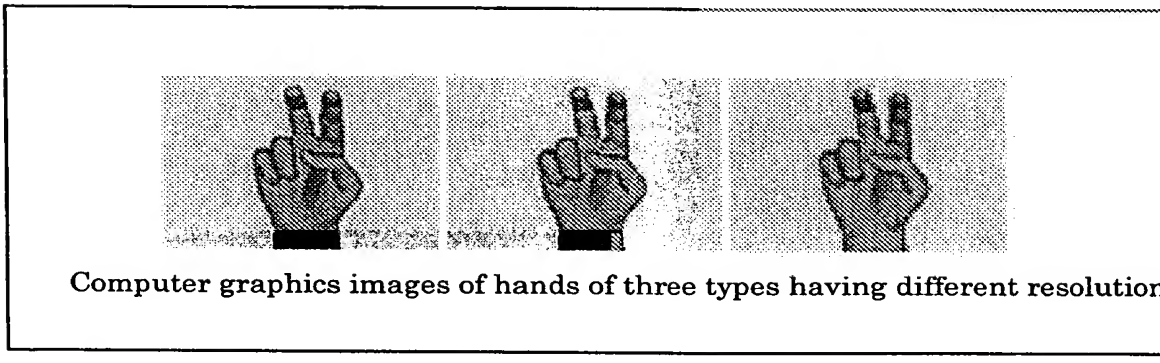
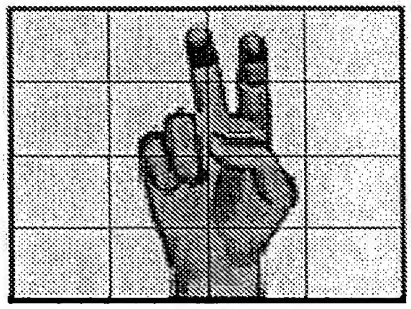

Computer graphics images of hands of three types having different resolutions

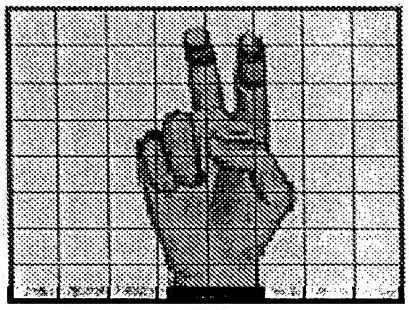
Fig.15

(A)



When one image is divided into 4 by 4 areas

(B)



When one image is divided into 8 by 8 areas

Fig.16

Number of image	1	2	3	4	▪ ▪ ▪	*p*
First principal component	No. 5	No. 256	No. 8375	No. 982		No. 7634
	Score 27.5	23.3	19.4	13.6	▪ ▪ ▪	−23.8
Second principal component	No. 6385	No. 247	No. 243	No. 115		No. 649
	Score 13.2	10.7	9.5	9.3		−15.7
▪ ▪ ▪		▪ ▪ ▪				
Tenth principal component	No. 9987	No. 8375	No. 46	No. 7426	▪ ▪ ▪	No. 11
	Score 1.2	1.1	1.0	0.9		−0.9

Appl. No. 10/595810
Filed With Amdt. Dated June 12, 2006
Page 13 of 21
Replacement Sheet

Fig.17

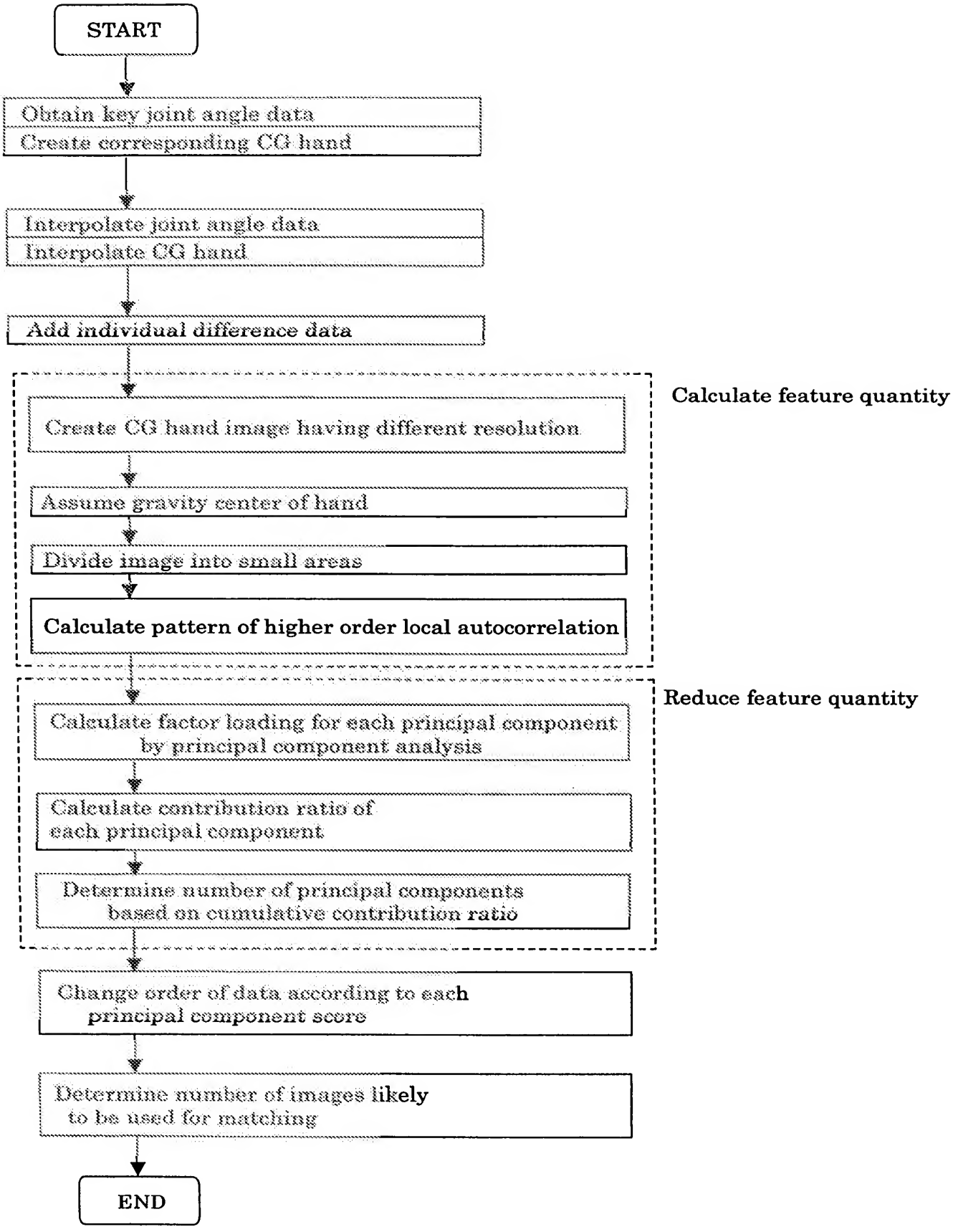

START
Obtain key joint angle data
Create corresponding CG hand
Interpolate joint angle data
Interpolate CG hand
Add individual difference data
Create CG hand image having different resolution
Assume gravity center of hand
Divide image into small areas
Calculate pattern of higher order local autocorrelation
Calculate feature quantity
Calculate factor loading for each principal component by principal component analysis
Calculate contribution ratio of each principal component
Determine number of principal components based on cumulative contribution ratio
Reduce feature quantity
Change order of data according to each principal component score
Determine number of images likely to be used for matching
END

Fig.18

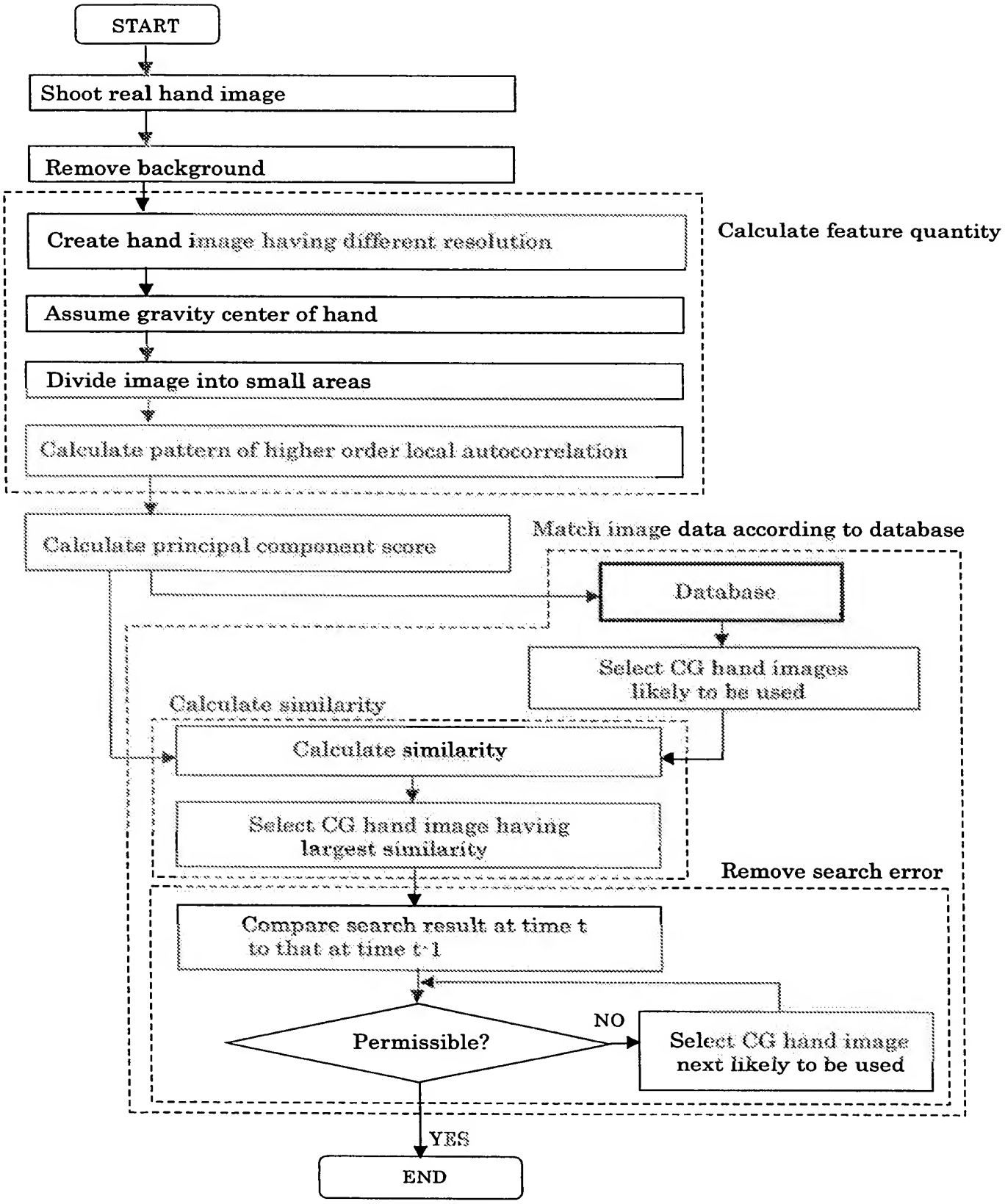

START
Shoot real hand image
Remove background
Create hand image having different resolution
Assume gravity center of hand
Divide image into small areas
Calculate pattern of higher order local autocorrelation
Calculate feature quantity
Calculate principal component score
Match image data according to database
Database
Select CG hand images likely to be used
Calculate similarity
Calculate similarity
Select CG hand image having largest similarity
Remove search error
Compare search result at time t to that at time t-1
Permissible?
NO
Select CG hand image next likely to be used
YES
END

Fig.19

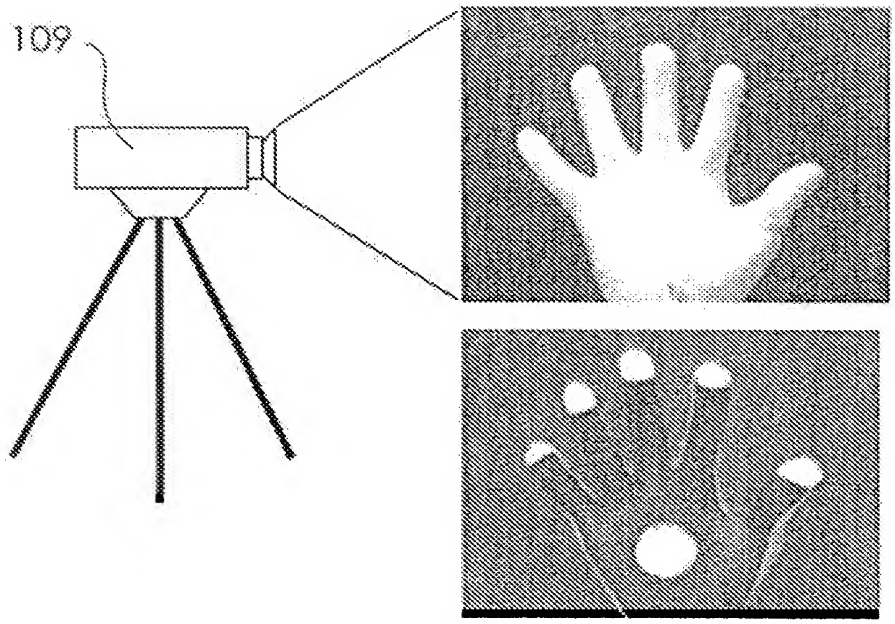

109

Fig.20

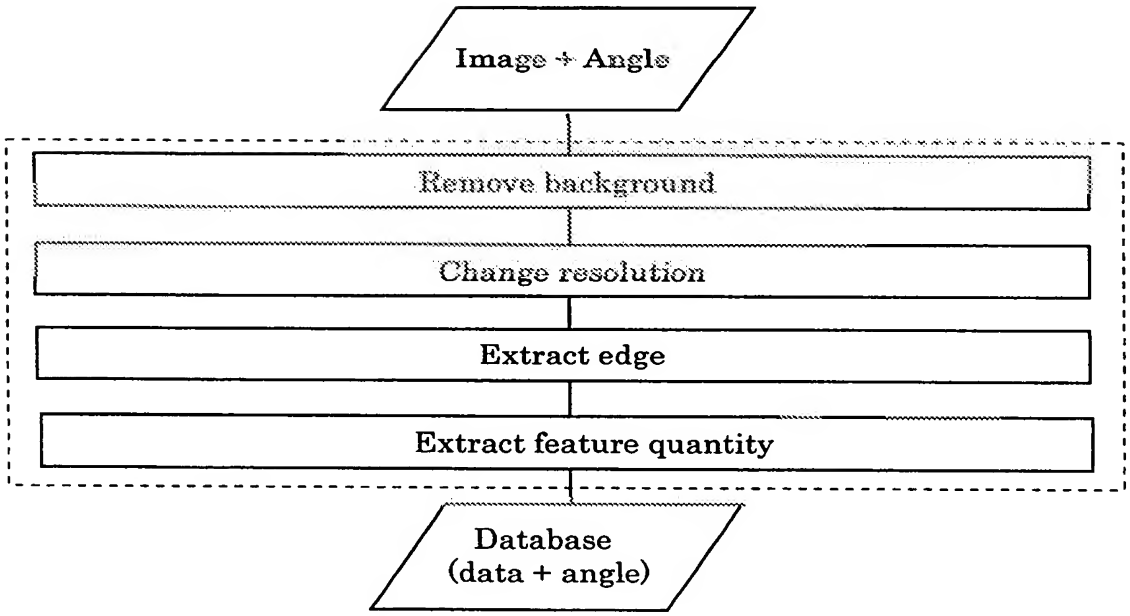


Image + Angle
Remove background
Change resolution
Extract edge
Extract feature quantity
Database
(data + angle)

Fig.21

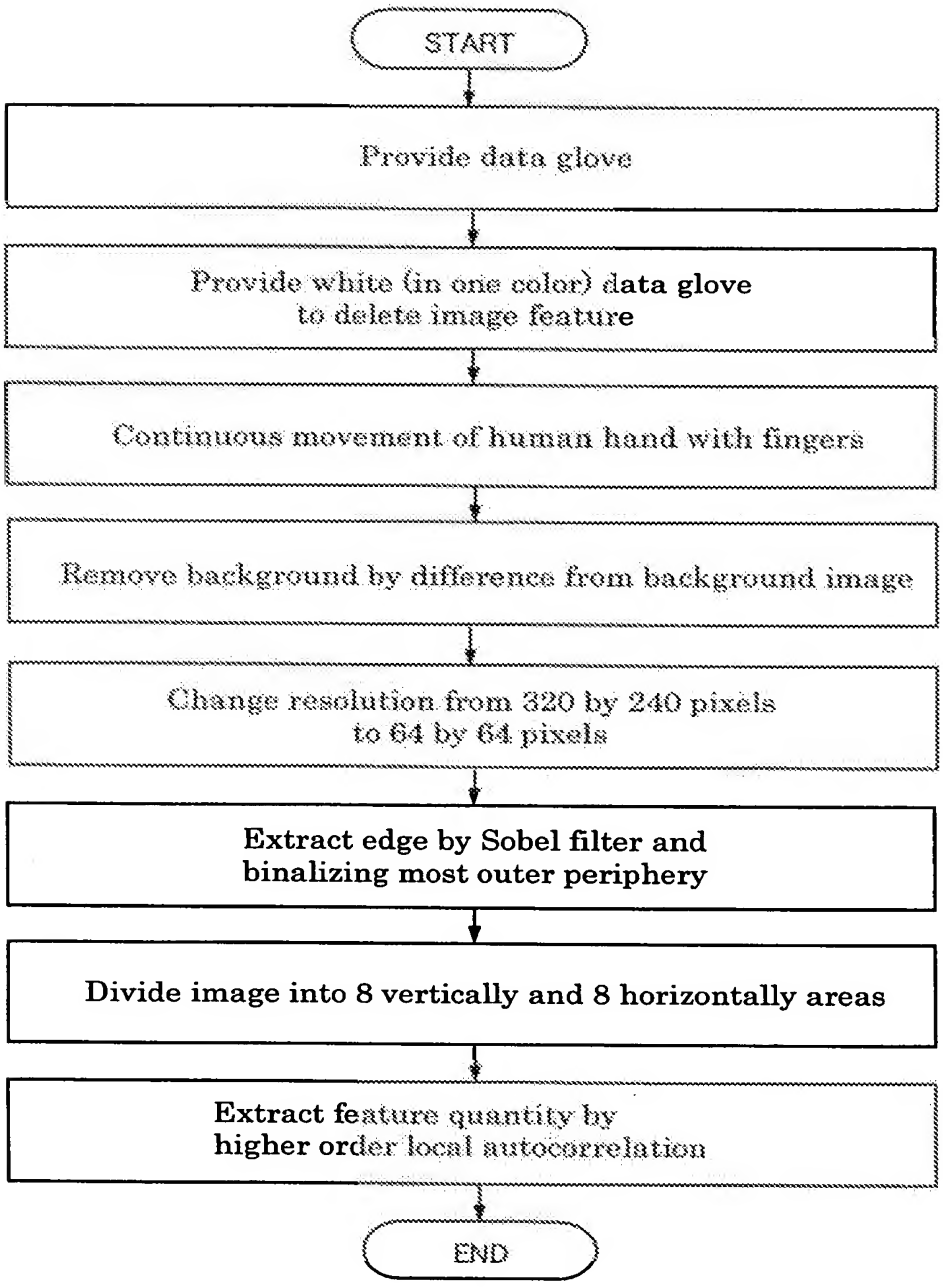

START
Provide data glove
Provide white (in one color) data glove to delete image feature
Continuous movement of human hand with fingers
Remove background by difference from background image
Change resolution from 320 by 240 pixels to 64 by 64 pixels
Extract edge by Sobel filter and binalizing most outer periphery
Divide image into 8 vertically and 8 horizontally areas
Extract feature quantity by higher order local autocorrelation
END

Fig.22

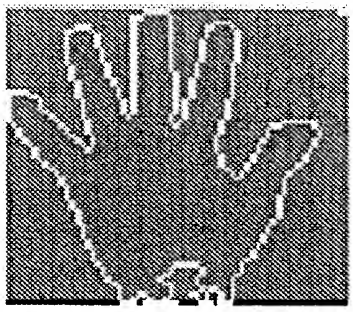


Fig.23

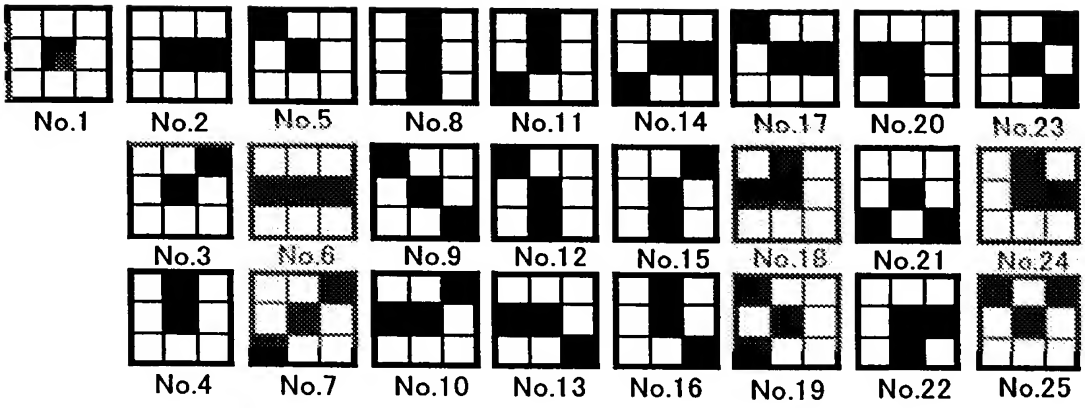

No.1
No.2
No.5
No.8
No.11
No.14
No.17
No.20
No.23
No.3
No.6
No.9
No.12
No.15
No.18
No.21
No.24
No.4
No.7
No.10
No.13
No.16
No.19
No.22
No.25

Fig.24

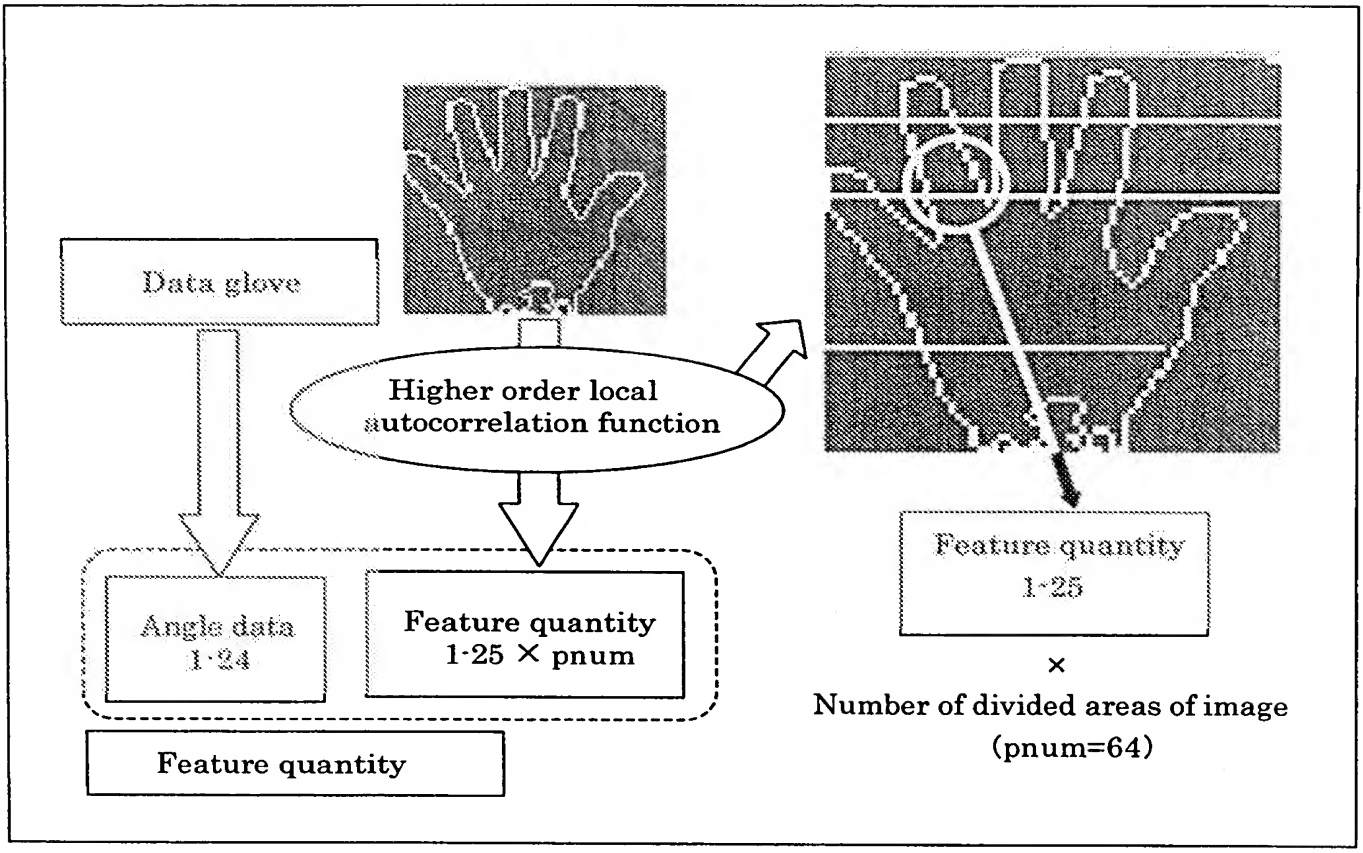

Data glove
Higher order local autocorrelation function
Angle data 1-24
Feature quantity 1-25 × pnum
Feature quantity
Feature quantity 1-25
×
Number of divided areas of image (pnum=64)

Fig.25

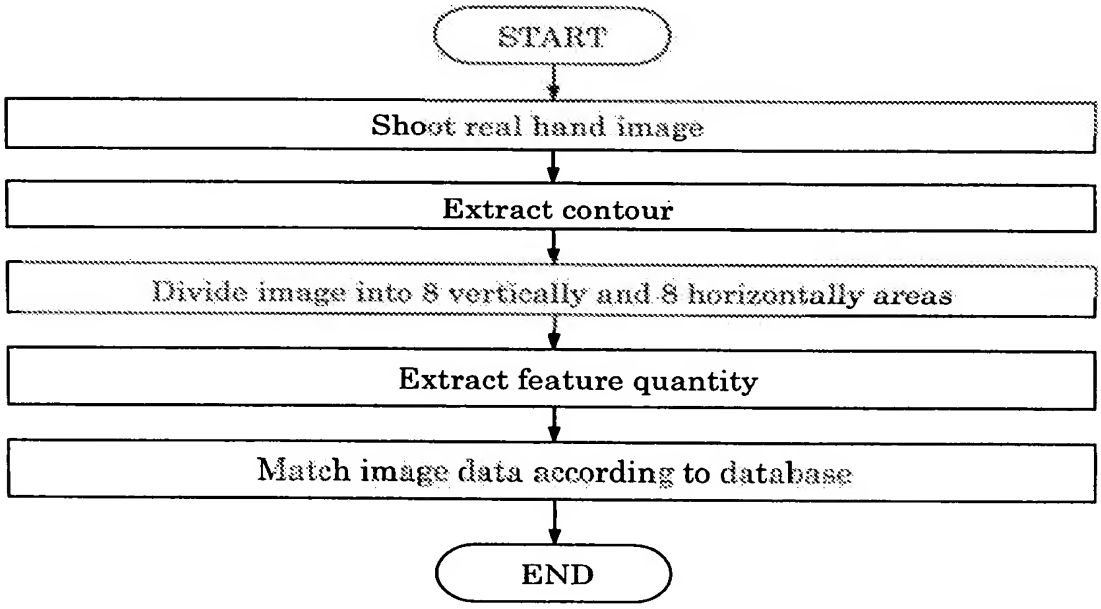

START
Shoot real hand image
Extract contour
Divide image into 8 vertically and 8 horizontally areas
Extract feature quantity
Match image data according to database
END

Fig.26

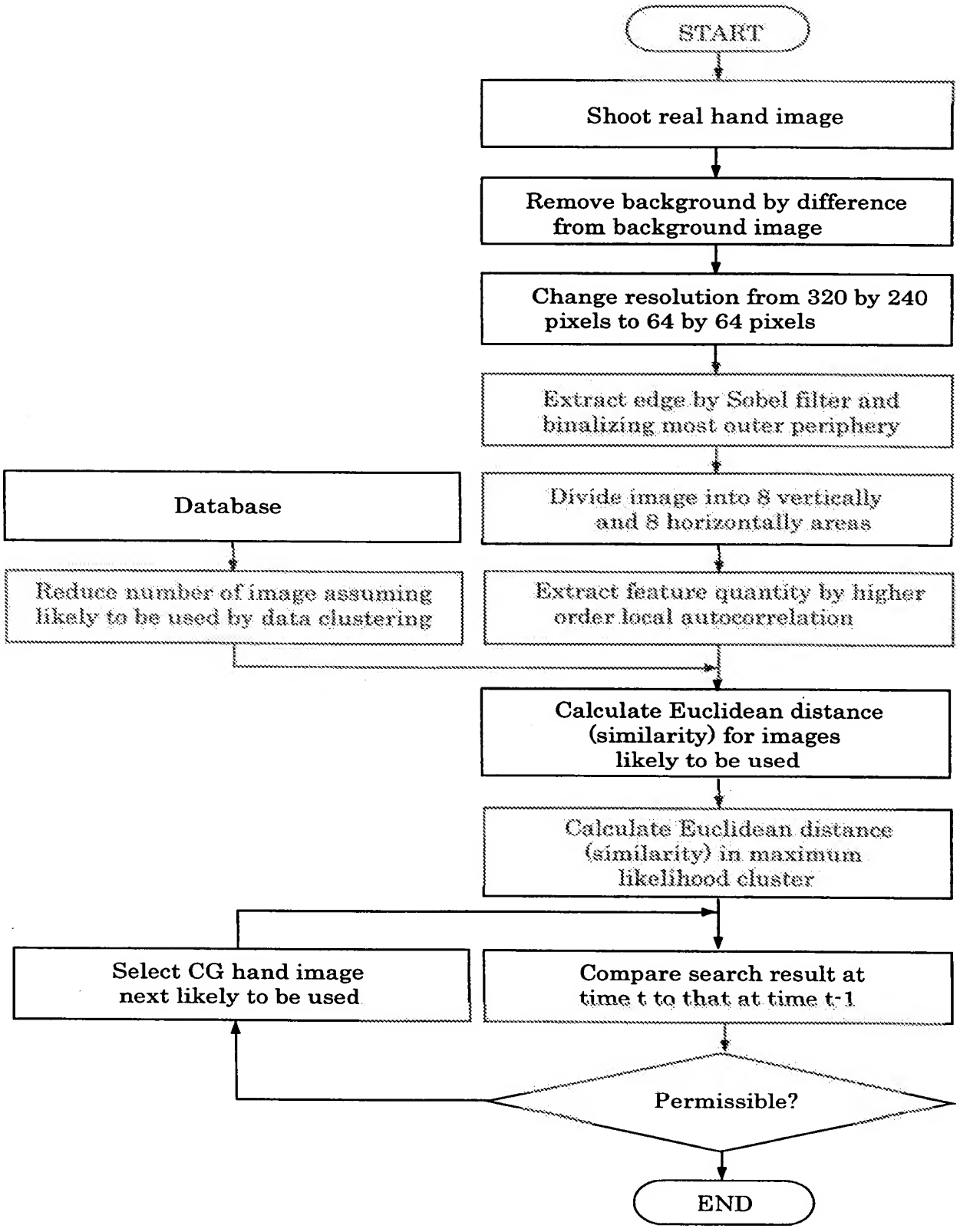

START
Shoot real hand image
Remove background by difference from background image
Change resolution from 320 by 240 pixels to 64 by 64 pixels
Extract edge by Sobel filter and binalizing most outer periphery
Database
Divide image into 8 vertically and 8 horizontally areas
Reduce number of image assuming likely to be used by data clustering
Extract feature quantity by higher order local autocorrelation
Calculate Euclidean distance (similarity) for images likely to be used
Calculate Euclidean distance (similarity) in maximum likelihood cluster
Select CG hand image next likely to be used
Compare search result at time t to that at time t-1
Permissible?
END

Fig.27

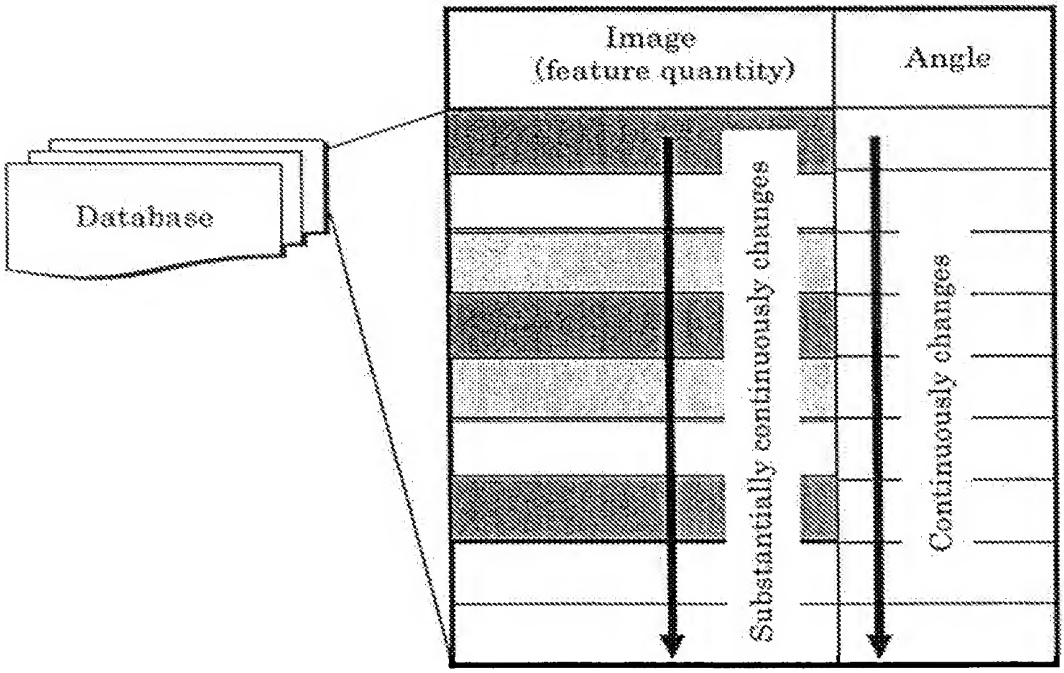


Image
(feature quantity)
Angle
Database
Substantially continuously changes
Continuously changes